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(71) Applicants (for all designated States except US): THE INSTITUTE OF CANCER RESEARCH [GB/GB]; 17A Onslow Gardens, London SW7 3AL (GB); THE WELLCOME FOUNDATION LIMITED [GB/GB]; Unicorn House, 160 Euston Road, London NW1 2BP (GB).					
(72) Inventors; and (75) Inventors/Applicants (for US only): GUSTERSON, Barry, Austin [GB/GB]; Institute of Cancer Research, Royal Cancer Hospital, Haddow Laboratories, 15 Cotswold Road, Sutton, Surrey SM2 5NG (GB); CROMPTON, Mark, Roger [GB/GB]; Institute of Cancer Research, Royal Cancer Hospital, Haddow Laboratories, 15 Cotswold Road, Sutton, Surrey SM2 5NG (GB); MITCHELL, Philip, John [GB/GB]; Institute of Cancer Research, Royal Cancer Hospital, Haddow Laboratories, 15 Cotswold Road, Sutton, Surrey SM2 5NG (GB); BARKER, Karen, Tracey [GB/GB]; Institute of Cancer Research, Royal Cancer Hospital, Haddow Laboratories, 15 Cotswold Road, Sutton, Surrey SM2 5NG (GB).					
(54) Title: CELL GROWTH FACTOR RECEPTORS					
(57) Abstract					
<p>The invention relates to a method of screening a substance for potential utility as a therapeutic agent in the treatment of cancer comprising providing a standard system in which a protein tyrosine kinase or an active fragment thereof is able to develop a measurable effect, allowing the protein tyrosine kinase to develop that effect in the presence and absence of the said substance and measuring the effect, ability to produce significant inhibition of the effect being taken as an indication of potential utility as a therapeutic agent, where the protein tyrosine kinase is characterised by the amino acid sequence of SEQ ID NO. 1 or an amino acid sequence showing a significant degree of homology thereto. The invention also relates to a therapeutic agent thus identified, to a method for detecting the protein tyrosine kinase and an enzyme substrate complex comprising the protein tyrosine kinase and a therapeutic agent capable of modulating the activity of the protein tyrosine kinase.</p>					

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CELL GROWTH FACTOR RECEPTORS

5 The present invention relates to cell growth factor receptors. More particularly the invention relates to the use of a tyrosine kinase growth factor receptor in the development of diagnostic and therapeutic approaches to cancer, for example breast cancer.

10 Protein tyrosine kinases are enzymes which show the property of catalysing the transfer of phosphate groups from donor molecules (ATP) to the hydroxyl groups of tyrosine residues in polypeptides. Known tyrosine kinases can be classified into two broad groups. Transmembrane tyrosine
15 kinases traverse cellular membranes so that they possess extracellular and intracellular domains. Cytoplasmic tyrosine kinases are located only intracellularly. A general feature of transmembrane (also referred to as receptor) tyrosine kinases is that they possess extracellular ligand-binding
20 domains, hydrophobic transmembrane sequences, and intracellular portions which include the tyrosine kinase domains (for a review see Ullrich & Schlessinger Cell, 61, 203-212 (1990)).

25 Tyrosine kinases can induce cell proliferation, cell transformation and regulate developmental events (see reviews by Hanks et al, Science, 241, 42-75 (1988) and Cantley et al, Cell 64, 281-302 (1991)). In general, where functional assays have been available (e.g. mitogenesis or transformation), it
30 has been shown that the biological functions of tyrosine kinases are usually dependent on intact enzyme activity and that through autophosphorylation and the phosphorylation of other proteins, they alter the subcellular localisation and activities of various components of the intracellular
35 signalling pathways.

Analysis of the oncogenes of many acutely transforming animal retroviruses has revealed that their products frequently manifest tyrosine kinase activity, as do the

products of their cellular proto-oncogene counterparts. Other genes encoding tyrosine kinases have been found to be altered by DNA rearrangements in cancer cells, the result being a presumed acquisition of cellular transforming activity (for example c-abl, c-met). Some cellular proto-oncogenes encoding tyrosine kinases have been cloned independently by virtue of the fact that they encode growth factor receptors, for example the epidermal growth factor receptor. On the other hand, the genes for other growth factor receptors which have tyrosine kinase activities, such as those for platelet-derived growth factor and insulin-like growth factors, have been well characterised, but have never been found to be transduced by retroviruses.

15 The c-erbB-2/HER2/c-neu gene encodes a transmembrane receptor-like tyrosine kinase which is structurally very similar to the EGF/TGF alpha receptor. The c-erbB-2 gene has been found to be overexpressed in 20 to 30% of human breast tumours, often in association with gene amplification, and this phenotype is now generally accepted as predictive of poor disease free and overall survival (for reviews see Sunderland & McGuire in Regulatory Mechanisms in Breast Cancer, Lippman & Dickson (Eds.), Kluwer Academic Publishers, Boston, pages 3 to 22 (1991) and Gusterson et al., J. Clin. Oncol., 10, 1049-1056 (1992)). Overexpression of the gene in fibroblasts induces transformation (di Fiore et al, Science, 237, 178-182 (1987) and Hudziak et al, Proc. Natl. Acad. Sci. (USA), 84, 7159-7162 (1987)), and ligands which bind to the c-erbB-2 gene product (human and rodent) and activate its tyrosine kinase activity have been identified (Lupu et al, Science, 249, 1552-1555 (1990), Dobashi et al, Proc. Natl. Acad. Sci. (USA), 88, 8582-8586 (1991), Wen et al, Cell, 69, 559-572 (1992) and Holmes et al, Science 256, 1205-1210 (1992)). Some of these ligands increase the rate of proliferation of cells expressing the c-erbB-2 protein. The strong implication of these and other findings is that overexpression of this tyrosine kinase in some breast tumour cells is one of the important steps in their progression towards tumourigenicity, and therefore that c-erbB-2 can function as an oncogene.

A variety of other receptor tyrosine kinases, including those for the IGFs and the FGFs, are expressed in breast tumours (Stewart et al, J. Biol. Chem., 265 21172-21178 (1990) and Wellstein & Lippman in Molecular Foundations of Oncology 5 Broder (Ed.), Williams and Wilkins, Baltimore, pages 403-418 (1991)), and the EGF/TGF alpha receptor is overexpressed in some cases (for example Horak et al, Oncogene, 6, 2277-2284 (1991)). As with c-erbB-2, overexpression of EGFs has been correlated with poor prognosis. Since the ligands of some of 10 these receptors can be detected in breast tumour samples, it may be that breast tumour development is also regulated by these molecules (for a review see van de Vijver & Nusse, Biochim, Biophys. Acta, 1072, 35-50 (1991)).

15 The features which are ideally required in a molecular target for tumour therapies include preferential expression in the tumours, a role in the development of the tumours (rather than merely being a marker), and a knowledge of the mechanism of its action as a starting point for the rational 20 design of activity modulators. It appears that all of these three criteria are satisfied, at least to some extent, in the case of c-erbB-2 and breast cancer and a considerable research effort is currently being directed to this molecule.

25 It has recently been found that the alkaloid K252a, at appropriate concentrations, selectively inhibits the tyrosine kinase and biological activities of the trk-class of neurotrophin receptors, but has no effect on the activities of v-src, v-fms or the receptors for EGF and PDGF, and also 30 does not affect general cell viability or proliferation (Tapley et al, Oncogene, 7, 371-381 (1992)). Members of another class of molecules, the tyrphostins, may be selective inhibitors of the EGF/c-erbB-2 class of tyrosine kinases (Gazit et al, J. Med. Chem., 34, 1896-1907 (1991)). An 35 antibody which inhibits the proliferation of human tumour cells by binding to the c-erbB-2 protein is currently under evaluation as a potential cancer therapy (Carter et al, Proc. Natl. Acad. Sci. (USA), 89, 4285-4289 (1992)).

If the transformation of a significant minority of breast tumour cells is due, at least in part, to the disregulated activity of the c-erbB-2 tyrosine kinase, then it seems likely that other breast tumours owe aspects of their transformed phenotype to the activity of other tyrosine kinases. The identification of further tumour associated tyrosine kinases would allow the development of novel diagnostic and therapeutic approaches to cancer and in particular breast tumours.

The cDNA cloning of a previously novel receptor tyrosine kinase from breast carcinoma cells has recently been reported (Johnson et al., Proc. Natl. Acad. Sci. USA, 90, 5679-5681 (June 1993)) and the DNA and predicted amino acid sequence of this protein are set out in SEQ ID NO. 1.

The predicted amino acid sequence is set out separately in SEQ ID NO. 2.

The authors designated this protein tyrosine kinase DDR (Discoidin domain receptor) and detected the transcription product of the DNA sequence in other human breast carcinoma cell lines and the translation product (protein) was also detected in breast carcinoma cell lines. However, the authors do not suggest that the protein tyrosine kinase plays any role as a tumour causative agent and no potential utility is suggested in the therapy or diagnosis of cancer, in particular human breast cancer.

Another recent disclosure suggests that the same protein tyrosine kinase has been detected in an epithelial ovarian cancer cell line (Laval et al, American Association for Cancer Research, Meeting, May 1993, Abstract No. 3144).

It has now been found that the receptor tyrosine kinase referred to above is expressed at a much higher level in human breast tumour cells than in normal breast. This suggests an

involvement of the tyrosine kinase in the transformation of breast cells. The present invention relates to the use of the tyrosine kinase as defined above in the diagnosis and/or therapy of cancer, particularly human breast tumours.

5

The present invention involves the use of a DNA isolate encoding a protein tyrosine kinase having the amino acid sequence shown in

SEQ ID NO. 1

10 or an amino acid sequence showing a significant degree of homology thereto, preferably at least 60% homology in the catalytic domain and at least 40% homology in the remainder of the molecule, more preferably at least 90% homology overall, for example at least 95% homology, or a fragment
15 thereof.

According to one embodiment, the DNA isolate encodes all of the amino acid sequence shown in the SEQ ID NO. 1 or an amino acid sequence showing a significant degree of homology
20 thereto. According to another embodiment the DNA isolate encodes a fragment of the amino acid sequence of the protein tyrosine kinase or an amino acid sequence showing a significant degree of homology thereto. DNA sequence encoding fragments of the protein tyrosine kinase preferably encodes
25 those parts of the amino acid sequence which characterise the enzyme, i.e. those parts which are most distinct from other protein tyrosine kinases. Most preferably the DNA sequence encodes all or part of the catalytic domain of the enzyme, i.e. amino acid residues 617 to 907 as shown in SEQ ID NO. 1.

30

The DNA isolate may have the base sequence defined in SEQ ID NO. 1 to encode the relevant amino acid sequence. Alternatively the DNA isolate may have any other DNA sequence encoding the relevant amino acid sequence.

35

The DNA isolate may take the form of a cloning vector or an expression vector preferably a plasmid vector, including DNA as defined above. In the case of an expression vector the DNA will be under control of an appropriate promoter and will

include regulatory elements required for expression in a suitable host cell.

The present invention also involves the use of a recombinant cell line transformed with an expression vector as defined above and capable of expressing a recombinant protein tyrosine kinase having amino acid sequence shown in

SEQ ID NO. 1

or an amino acid sequence showing a significant degree of homology thereto or a fragment thereof.

Suitable host cells include mammalian cells, insect cells, yeast cells and bacterial cells and the expression vector will include a promoter and other regulatory elements appropriate to the host cell in question. Preferred host cells include CHO cells, myeloma cells, primary immortalised human breast cells, rodent fibroblast cell lines, baculovirus cells, yeast and *E. coli* cells. General techniques for manipulating DNA coding sequences and expressing such sequences in various types of cells are well known to those skilled in the art and are described for example in Sambrook et al, *Molecular Cloning: A Laboratory Manual*, 2nd Edition, Cold Spring Harbor Laboratory.

The present invention also involves the use of a protein tyrosine kinase having the amino acid sequence shown in

SEQ ID NO. 1

or an amino acid sequence showing a significant degree of homology thereto or a fragment thereof.

The protein tyrosine kinase or a fragment thereof may be a recombinant polypeptide produced as the expression product of a coding sequence as defined above in a recombinant cell line. Alternatively the protein tyrosine kinase may be produced in a human tumour cell line. In either case the protein may be extracted and purified by standard techniques, for example antibody affinity chromatography. The glycosylation of the protein (if any) will depend on the cells in which it is produced and protein produced in human tumour

cells in culture should have glycosylation equivalent to that produced *in vivo* in human tumours.

Part of the DNA sequence encoding the protein tyrosine kinase set out in SEQ ID NO. 1 was isolated in the manner described in more detail in the example set out below but which involves briefly the following steps:

- i) isolation of mRNA from tumour metastatic tissue;
- ii) preparation of cDNA from the isolated mRNA;
- iii) PCR amplification using degenerate oligonucleotide primers designed to amplify sequence associated with protein tyrosine kinases;
- iv) subcloning PCR products;
- v) identification of protein tyrosine kinase products amplified at higher levels from tumour bearing tissue;
- vi) DNA sequencing and identification of novel protein tyrosine kinase sequence;
- vii) isolation of cDNA sequence 3' of the region amplified by 3' RACE PCR.

Application of the above protocol identified part of the DNA sequence for the protein tyrosine kinase which was designated PTK22 and which corresponds to the protein tyrosine kinase designated DDR by Johnson et al (Supra). As already noted, the enzyme has now been shown to be overexpressed in certain human breast tumours as compared to normal breast tissue.

The present invention thus relates to the application of the tyrosine kinases for the development of therapeutic, prognostic and diagnostic approaches to cancer. The invention is particularly applicable to breast cancer, however, the same approaches may also be applicable to other cancers and research data suggests a connection between breast cancer and ovarian cancer and also between these two cancers and gastric cancer.

In terms of therapy, the involvement of the tyrosine kinase in tumours means that beneficial clinical effects in

the treatment of tumours can be obtained by modulating the tyrosine kinase activity and/or the functionality of the receptor. There are a number of ways in which such modulation could be achieved.

5

The activity of the protein tyrosine kinase could be significantly impaired or inhibited by small chemical molecules and screens to identify suitable small molecular weight inhibitors can be developed as described in more detail below. This approach is analogous to that proposed for other tyrosine kinases (see "Drugs of the Future", 17(2), 119-131, (1992)). A further embodiment of this approach would be to derive nmr spectra or crystal structures for the protein tyrosine kinases or domains thereof and use the structural information so obtained to synthesise chemical structures de novo which could be similarly screened for activity as inhibitors.

The approach described above could be extended to encompass small peptides which are either competitive for signalling action of the tyrosine kinase receptor, or which demonstrate useful binding thereto, such that the receptor function is inhibited. This would include, for example, peptides which are capable of blocking substrate binding to the receptor, including but not limited to those which bear SH2 domains. An additional approach is to use small molecules or peptides to block or interfere with ligand activation or dimerisation of the tyrosine kinase. Both of these events are generally required to effect a biological signal so that blocking or inhibition thereof could be used to therapeutic effect.

Macromolecules, such as antibodies, could also be used as inhibitory molecules to block receptor function. This would be particularly applicable to antibodies raised against the extracellular domain of the protein tyrosine kinase where antibodies could promote internalisation or interfere with ligand binding. Either of these situations could produce significant modulation (positive or negative) of the activity

of the protein.

Protein tyrosine kinase function could also be blocked by expressing or administering a peptide which is a truncated or altered version of the protein. These are typically referred to as dominant negative proteins and are believed to sequester the active protein in a non-functional complex. Protein tyrosine kinase function could also be modulated by blocking translation of the mRNA encoding the protein using antisense oligonucleotides.

A further regulatory role of the protein tyrosine kinase could be manipulated by controlling expression or activity of specific phosphatases which control the degree of protein phosphorylation. It is recognised that the phosphorylation of specific residues, particularly tyrosine, threonine and serine residues, play an important role in transmitting a biological signal from the tyrosine kinase.

Use of the above therapeutic approaches depends on the identification and/or development of suitable agents for modulating, for example inhibiting, particular functions or activities of the protein tyrosine kinase. The present invention thus relates to assays or screens by which such agents can be identified.

The present invention provides a method of screening a substance for potential utility as a therapeutic agent in the treatment of cancer, in particular breast cancer, which comprises providing a standard system in which a protein tyrosine kinase or an active fragment thereof is able to develop a measurable effect, allowing the protein tyrosine kinase to develop that effect in the presence and absence of the said substance and measuring that effect, ability to produce significant inhibition of the effect being taken as an indication of potential utility as a therapeutic agent, wherein the protein tyrosine kinase is characterised by the amino acid sequence shown in

SEQ ID NO. 1

or an amino acid sequence showing a significant degree of homology thereto.

In accordance with this general principle, screens for potential therapeutic agents can take a number of forms. For example an initial screen to determine whether or not a substance merits further investigation as a potential inhibitor of the protein tyrosine kinase will usually be biochemical and should preferably be simple, rapid and capable of high through-put. Such screens will often make use of the protein expressed in a recombinant expression system or derived from a cellular source in which the protein is overexpressed. Particularly suitable recombinant expression systems include insect baculovirus, and the use of primary immortalised human breast cell lines, or rodent fibroblast cell lines as host cells. The protein is then used directly in an *in vitro* assay with and without the potential inhibitor. This gives rapid data on the performance of the substance as an inhibitor often providing direct evidence that the substance can inhibit the enzymic activity of the protein tyrosine kinase and thus merits further study. This type of isolated system can also provide data on specificity but will not generally provide any information on bioavailability. The enzymic activity of the protein tyrosine kinase in vitro can be measured, for example, by measuring autophosphorylation or phosphorylation of a model substrate, by following incorporation of radioactive phosphate or by using anti-phosphotyrosine antibodies.

Further information concerning potential inhibitors can be provided by cell based screens which make use of a phenotypic alteration, e.g. a change in morphology and/or tumorigenicity, conferred by expression of the protein tyrosine kinase in a recombinant cell line or overexpression in any other available cell line. Particularly suitable recombinant cell lines again use primary immortalised human breast cell lines or rodent fibroblast cell lines as host cells. The cells can be used in proliferation or tumorigenicity assays with and without the potential inhibitor

looking for substances able to halt growth of and/or morphologically de-transform the cells. A control for substances which are generally cytotoxic can be provided by the same parental cell line engineered to express another oncogene which transforms the cells at a signalling point downstream of the protein tyrosine kinase. Assays of this sort can be very informative and they may provide data on mode of action of inhibitors.

The final stage of screening is the development of animal screens. These are time consuming and expensive and for these and ethical reasons their use is kept to a minimum, however they can give vital information regarding metabolism, clearance and performance of a substance in a true in vivo system which cannot be obtained in other ways. Animal screens ideally use the same recombinant or other cell lines as described above which express the protein tyrosine kinase. The cells are used as xenografts in animals, for example, nude mice, to give tumours whose growth is controlled by expression of the protein tyrosine kinase. The mice are then given inhibitors to determine whether they are capable of causing the selective regression of the xenografts without blocking the growth of a control xenograft. Alternatively transgenic animals which develop tumours by virtue of the appropriate tissue specific expression of the target protein tyrosine kinase can be used in a similar manner.

The invention also extends to therapeutic agents identified by use of any or all of the screens referred to above. Preferably the therapeutic agent is a chemical molecule of relatively low molecular weight, for example, less than about 1000. Examples of suitable classes of molecule include staurosporine analogues, tyrphostins and flavonoids. Alternatively, the therapeutic agent can be a macromolecule, for example an antibody raised against the extracellular domain of the protein tyrosine kinase. The therapeutic agent can also be a peptide or an antisense oligonucleotide capable of blocking translation of the mRNA encoding the protein tyrosine kinase.

The invention also extends to an enzyme-substrate complex which comprises a protein tyrosine kinase characterised by the amino acid sequence shown in

SEQ ID NO. 1

- 5 or an amino acid sequence showing a significant degree of homology thereto and a therapeutic agent capable of modulating the activity of the said protein tyrosine kinase.

- The protein tyrosine kinases can also be used in
- 10 prognostic and diagnostic applications. Thus antibodies raised against the protein tyrosine kinase or nucleic acid encoding the tyrosine kinase can be used as the basis for screening tissue, in particular tumour tissue, for the presence of the protein tyrosine kinases. If, as in the case
- 15 of c-erbB-2, the expression of the tyrosine kinase correlates with poor prognosis, then treatment of the patient could be modified accordingly. Similarly, again as with c-erbB-2, there may be situations where parts of the receptor are "shed" into the bloodstream. In this case, the presence of the
- 20 receptor could be detected, for example, by use of an ELISA assay, and this would be a useful diagnostic tool for the identification of patients predisposed to develop or liable to develop tumours, in particular breast cancer.

- 25 Accordingly the present invention provides a method for detecting a tyrosine kinase having an amino acid sequence as defined in

SEQ ID NO. 1

- or a fragment thereof which comprises reacting a test sample
- 30 with a specific antibody raised against an antigen from the said amino acid sequence and determining whether there is any antigen-antibody binding within the test sample. The test sample may be for example a tissue sample, such as a tumour sample, or a blood sample and presence of abnormal amounts of
- 35 the protein tyrosine kinase may indicate development of or susceptibility to develop a tumour.

The invention also provides a method for the detection in a sample of DNA a nucleic acid sequence encoding a tyrosine

Kinase which comprises subjecting the sample or nucleic acid isolated therefrom to a method capable of detecting a nucleic acid sequence therein identical or substantially homologous to a defined nucleic acid sequence and identifying any sequence identical or substantially homologous to all or part of the DNA sequence defined in

SEQ ID NO. 1,

or mRNA which would be the transcription product of such DNA. Again, presence of abnormal amounts of nucleic acid encoding the protein tyrosine kinase may indicate development of or susceptibility to develop a tumour.

Suitable methods for the detection of specific DNA sequences include Southern blotting and/or PCR using appropriate primers. Suitable methods for detecting mRNA include Northern blotting, RNase protection studies and direct nucleic acid *in situ* hybridisation.

EXAMPLE

Experimental work on which the invention is based is described in more detail in this Example in which reference is made to the accompanying drawings in which:

Figure 1 shows a Northern blot to examine expression of DDR mRNA in human axillary lymph nodes. 5µg of total RNA were loaded per lane. Approximately 4 Kb DDR transcript (upper panel). Ethidium bromide staining of 28S rRNA, to demonstrate RNA loading, is shown (bottom panel).

Figure 2 shows *in situ* hybridisation to examine DDR expression in an involved lymph node. Light and dark field images are on the left and right respectively. Specific probe (DDR) and control (Cont.) are shown. Oligonucleotide probes were used. Magnification x 200.

Figure 3 shows a Northern blot to examine DDR expression in human breast tissue. 10µg of total RNA per lane. Upper panel shows DDR transcript, lower panel ethidium bromide stained 28S

rRNA.

Figure 4 shows DDR expression in murine mammary development. 2µg Poly (A)+ RNA per lane. DDR transcript shown in upper panel. Blot was hybridised with GAPDH to demonstrate RNA loading (lower panel).

Figure 5 shows Northern blot analysis of DDR expression in human cell lines performed as for Figure 1. DDR transcript (upper panel), ethidium bromide stained 28S rRNA (lower panel).

Figure 6 shows *in situ* hybridisation analysis of DDR expression in human breast tumour tissue. Tissues were from three different individuals: a, b and c. In each panel, light and dark field images are on the left and right respectively. Specific probes are shown (DDR), and controls (Cont.). il= infiltrating lymphocytes, tu= tumour and ne= normal epithelium. Experiments 6a and 6b used oligonucleotides probes, and 6c used RNA probes. Magnification x 200.

Figure 7 shows DDR expression in normal tissues. a) human multiple tissue Northern blot containing 2µg poly (A)+ RNA per lane. DDR transcript shown in upper panel. Blot was stripped and rehybridised with human GAPDH probe to demonstrate RNA loading (lower panel). b) Total RNA Northern blot, 10µg RNA per lane, DDR transcript upper panel, ethidium bromide stained 28S rRNA lower panel.

MATERIALS AND METHODS

Tissues

Human tumour bearing or non-involved lymph nodes, tumour and normal tissue samples were obtained from surgery and rapidly frozen in liquid nitrogen. Normal breast tissue was obtained from reduction mammoplasty. Murine mammary tissue was obtained by excision of the fourth gland, removal of the associated lymph node, and rapid freezing in liquid nitrogen. All tissues were stored at -70°C or in liquid nitrogen.

Histopathological examination determined the presence or absence of metastases in the lymph nodes.

Cell lines

- 5 CAL 51, a human breast carcinoma cell line, was isolated and described by Gioanni et al (Br. J. Cancer, 62, 8-13 (1990)). The fibrosarcoma cell line HT1080, and the other breast cancer cell lines were purchased from the American Type Culture Collection. Cells were cultured according to conditions
10 recommended by the suppliers.

RNA extraction

- Total RNA was extracted from all tissues and cell lines by the method of Chomczynski and Sacchi (Anal. Biochem., 162, 156-159
15 (1987)). Poly (A)+ RNA was isolated from murine mammary gland total RNA samples using the Poly A+ Tract Kit (Promega) according to the manufacturer's instructions, except that mRNA was eluted with three washes (2 x 200µl, 1 x 100µl) of water.

20 RT-PCR and PTK differential screen

- 5µg of total RNA purified from involved or non-involved lymph nodes was digested with 10 units of RNase free DNase 1 (Pharmacia) using the manufacturer's recommended conditions in the presence of 40 units of RNase inhibitor (Boehringer
25 Mannheim). Samples were heated to 100°C for 1 minute (min) to inactivate the DNase, extracted with phenol/chloroform and precipitated with ethanol. For cDNA synthesis, 2.5µg of RNA was resuspended in water and denatured at 65°C for 3 min in the presence of 40 ng pd(N)₆ random hexamers (Pharmacia) and cooled on ice. Reverse transcription was carried out using
30 1 mM dNTPs (Pharmacia), 40 units RNase inhibitor, 30 units of AMV reverse transcriptase SL (Life Sciences) and the buffer provided by the manufacturer at 41°C for 1 hour. Control reactions were performed as above but omitting the reverse
35 transcriptase enzyme (RT-control). To inactivate the inhibitory properties of reverse transcriptase on Taq polymerase, samples were heated to 100°C for 1 min.

Degenerate oligonucleotides were designed to amplify by PCT

an approximately 200 bp region encoding part of the catalytic domain of PTKs. The highly conserved amino acid sequence shown in

SEQ ID NO. 3

5 was used for designing the 5' oligonucleotide shown in

SEQ ID NO. 4

and the highly conserved amino acid sequence shown in

SEQ ID NO. 5

was used for designing the 3' oligonucleotide shown in

10 SEQ ID NO. 6.

Amplifications were carried out using cDNA derived from 0.5µg of original RNA in 60 mM KCl, 15mM Tris-HCl, 1.1mM MgCl₂, 200µM of each dNTP, 0.5ng of each primer and 2 units of Taq polymerase (Cetus). The reaction mixtures were cycled 30

15 times at 94°C for 1 min, 55°C for 2 min and 72°C for 1 min.

For each sample, PCR was carried out on cDNA and the relevant RT-control. The amplified products were electrophoresed

through 3% agarose gels, the approximately 200 bp band excised and purified using a Mermaid kit (Bio 101). PCR products from

20 involved nodes were subcloned into the PCR II vector

(Invitrogen) according to the manufacturer's instructions.

Clones were picked, grown in liquid culture, pelleted,

resuspended in denaturing solution (0.5M NaOH, 1.5M NaCl) and

aliquots were gridded onto duplicate Hybond-N membranes

25 (Amersham). Filters were then neutralised in 3M NaCl, 0.5M

Tris-HCl (pH 7.4). Duplicate filters were hybridised with ³²P

labelled randomly primed (Feinberg & Vogelstein, Anal.

Biochem, 132, 6-13 (1983); and Feinberg & Vogelstein, Anal.

Biochem, 137, 266-267 (1984)) PCR products from either the

30 involved or non-involved node. Clones containing PTK

fragments that hybridised more strongly with the involved

node-derived probe compared with the non-involved node derived

probe were chosen for sequence analysis.

35 DNA sequencing

Templates for sequencing were prepared by the rapid method of Yie et al (Nucleic Acids Res., 21, 361(1993)) and were

sequenced by the dideoxy method of Sanger et al, (Proc. Natl.

Acad. Sci. (USA), 74, 5463-5467 (1977)) using a Sequenase

Version 2.0 kit (United States Biochemicals).

3' RACE-PCR

To isolate cDNA sequences 3' to the region amplified by the PTK PCR, a modification of the RACE protocol described by Frohman et al (Proc. Natl. Acad. Sci. (USA), 85, 8998-9002 (1988)) was used. RNA from human breast carcinoma cell line MDA MG 468 was reverse transcribed using the tagged oligo d(T) primer shown in

10 SEQ ID NO. 7.

Two nested sense oligonucleotides were used in consecutive PCR reactions. The upstream sense primer was as shown in

SEQ ID NO. 8

and the downstream sense primer was as shown in

15 SEQ ID NO. 9.

The tag sequence used with oligo d(T) for the reverse transcription was used as the antisense primer in both amplifications. The reaction buffer was as described for the PTK PCR except $MgCl_2$ was used at 1.5mM, cycling parameters were 94°C for 1 min 15 seconds, 56°C for 2 min and 72°C for 2 min.

Northern blots

Human total RNA samples were electrophoresed through formaldehyde/agarose gels, transferred to Hybond-N membranes (Amersham) and fixed by U.V. illumination. The human multiple tissue Northern blot was purchased from Clontech. Murine Poly (A)+ RNA samples were fractionated in agarose gels containing glyoxal/DMSO, transferred to ZetaProbe membranes (Biorad) and fixed by baking at 80°C for 2 hours. ^{32}P labelled probes were prepared as described by Feinberg & Vogelstein (supra). Hybridisations were carried out according to the manufacturer's instructions, membranes were washed to a final stringency of 0.1 x SSC, 0.1% SDS at 65°C.

35

Probe generation for *in situ* hybridisation

Riboprobes: The DDR RACE PCR fragment was sub-cloned into pBluescript KS⁺ (Stratagene) and sense and antisense RNAs labelled with ^{35}S -UTP (Amersham) were synthesised. The

transcription reactions were carried out using a Stratagene Transcription kit according to the manufacturer's instruction. Probes were subject to limited alkaline hydrolysis at 65°C for 100 min (Cox et al., Developmental Biology, 101, 485-502 (1984)) to achieve a final length of between 100-200 bases. Full length and hydrolysed probes were examined on formaldehyde/agarose gels.

Oligonucleotide probes: Antisense 30mer oligonucleotides as follows were synthesised to the 3' untranslated and catalytic domain encoding regions of DDR:-

SEQ ID NO. 10

SEQ ID NO. 11

SEQ ID NO. 12

SEQ ID NO. 13.

A 30mer random oligonucleotide N₃₀ was also synthesised (randomer).

The oligonucleotides were 3'-labelled with ³³P-dATP (Amersham) using terminal transferase according to manufacturer's instructions (Boehringer Mannheim). Probes were purified by passing through Chroma-spin 10 columns (Clontech) to remove unincorporated label. Tail lengths were analysed on a DNA sequencing gel. The four specific oligonucleotides were then mixed equally to form a cocktail.

Labelling efficiency of all probes was assessed by scintillation counting.

In situ hybridisation

Except those used in post-hybridisation steps, all solutions were diethylpyrocarbonate treated and all glassware was baked.

7µm cryostat sections were cut from snap frozen human tumour material which had been excised during surgery, and stored in either liquid nitrogen or at -80°C. Sections were dried onto APTES (3-aminopropyltriethoxysilane) treated slides (Rentrop et al., Histochem. J., 18, 271-276 (1986)) over dry ice, and fixed at 4°C in 4% paraformaldehyde, phosphate buffered saline

(PBS) for 15 min, followed by two 15 min washes in PBS. The sections were dehydrated through ethanols from 30%-100%, air dried, and stored at -80°C until required.

5 a) With riboprobes

Sections were equilibrated to room temperature for 5 min, quickly rehydrated through ethanols from 100% to 30%, and washed twice for 5 min in PBS. Sections were acetylated for 10 min in 0.1M triethanolamine, 0.25% acetic anhydride while stirring. After washing in 2xSSC for 2 min, denaturation of tissue RNAs was carried out in 50% formamide, 2xSSC for 10 min at 60°C. Sections were then dehydrated and air dried.

15 Hybridisation was performed overnight in buffer (50% formamide, 0.3M NaCl, 10mM Tris-HCl pH8, 2mM EDTA pH8, 10% dextran sulphate, 10mM sodium phosphate pH8, 50µgml⁻¹ ssDNA) with comparable counts per minute (cpm) of either antisense or sense riboprobes, in a humid chamber at 50°C.

20 After hybridisation, two 30 min washes in 2xSSC, 50% formamide at 60°C were followed by treatment with 20µgml⁻¹ RNase A in 0.5M NaCl, 10mM Tris HCl pH7.5, 5mM EDTA pH 7.5 for 30 min at 37°C. Sections were washed for 15 min in 2xSSC at 60°C, followed by two final washes at a stringency of 0.1xSSC for 30 min at 60°C. Sections were dehydrated and air dried before autoradiography.

b) With oligonucleotide probes.

30 Sections were equilibrated to room temperature, rehydrated, washed and acetylated as described for sections hybridised with riboprobes. After washing twice for 5 min with PBS they were dehydrated and air dried.

35 Sections were overlaid with 10µl of hybridisation buffer (6x SSC, 50% formamide, 5x Denhardt's solution (Sambrook et al., Molecular Cloning: A Laboratory Manual. 2nd Edn., Cold Spring Harbor Laboratory Press, USA (1989)), 10% dextran sulphate)

containing $20\mu\text{gml}^{-1}$ unlabelled random oligonucleotide, and prehybridised for 3 hours at 37°C in a sealed humid chamber. After prehybridisation, a further $10\mu\text{l}$ of hybridisation buffer containing comparable cpm of either the labelled oligonucleotide cocktail or labelled randomer were added to each section and gently mixed with prehybridisation solution. The sections were incubated overnight at 37°C (Lathé, *In Situ Hybridisation Principles and Practice*, Polak & McGee (eds.) Oxford Scientific Publications, Oxford pp71-80 (1989)) in a sealed humid chamber.

Sections were removed from the chamber, and the hybridisation solution was rinsed off with prewarmed $5\times\text{SSC}$ gently pipetted over the slide. The area around the sections was dried and the sections were then overlaid with $20\mu\text{l}$ prehybridisation solution ($20\mu\text{gml}^{-1}$ randomer) and incubated for 60 min as before. This process might help reduce background by replacing non-specifically bound oligonucleotide with random oligonucleotide. This step was repeated once. Slides were washed to a final stringency of 60% formamide, $5\times\text{SSC}$ at 37°C . Sections were dehydrated in 70% and 100% ethanol and air dried.

Autoradiography on tissues

This process was the same for both riboprobe and oligonucleotide methods. In order to give a guideline of the length of time of exposure to photographic emulsion required, slides were placed against autoradiography film overnight. Slides were dipped in K.5 (Ilford) photographic emulsion diluted 1:1 with 2% glycerol, following manufacturer's guidelines. Slides were dried in an air-tight container with desiccant at room temperature for 2 hours and stored dry at 4°C , in a light-tight box for the required length of time. Slides were developed in D19 (Kodak), stopped in 1% acetic acid, 1% glycerol and fixed in 30% sodium thiosulphate. Sections were counter stained in 0.02% toluidine blue, mounted in DPX (Fisons) and examined by light and darkfield microscopy.

RESULTS

Identification of PTKs in a differential screen of involved and non-involved lymph nodes

5 RNA was isolated from involved and non-involved axillary lymph nodes from patients with metastatic breast tumours. RT-PCR was performed on the RNA using degenerate oligonucleotides encoding the amino acid sequences shown in SEQ ID NO. 3 and
10 SEQ ID NO 5, sequences highly conserved in PTKs (Hanks, Science, 241, 42-52. (1988)). The resultant pools of approximately 200bp PTK cDNA fragments from the involved nodes were subcloned, and clones screened with mixed pools of radiolabelled PTK fragments from both involved and non-involved nodes. Clones amplified preferentially from the
15 involved nodes were sequenced. For each of five involved lymph nodes, 50 or 100 clones were screened; differentially amplified cDNAs were found in four of five nodes. A novel kinase was detected as the major differentially amplified PTK-encoding cDNA; it showed similarities with trk A (Martin-Zanca
20 et al, Nature, 319, 743-748 (1986)) and the rat PCR generated fragment tyro 10 (Lai & Lemke, Neuron, 6, 691-704 (1991)). The receptor PTK c-erb-B2 was found at high levels in three nodes.

25 The trk A/tyro 10-like PTK is identical to DDR
To study the expression patterns of the trk-like kinase, a 3' Rapid Amplification of cDNA Ends (RACE)-PCR fragment was generated using two specific nested oligonucleotides corresponding to the sequence between the two degenerate
30 primers. Dideoxy sequencing of this 1.2 kilo base (kb) 3' RACE-PCR fragment revealed 384 nucleotides of predicted coding sequence. This comprised sequences encoding part of a putative PTK catalytic domain, which showed similarity to trk A, followed by a short C terminal domain of 8 amino acids
35 after subdomain XI. While analysing this fragment, a report was published describing a receptor PTK found in cultured breast carcinoma cells lines with an extracellular discoidin 1-like domain (DDR) (Johnson et al, Proc. Natl. Acad. Sci. (USA), 90, 5677-5681 (1993)). Comparison of the DDR sequence

with the 3' RACE-PCR fragment revealed them to be identical, the 3' RACE-PCR fragment begins at nucleotide position 2500 of the published DDR sequence.

5 **Expression of DDR mRNA in lymph nodes**

DDR was detected in a PCR based differential screen designed to identity PTKs expressed at higher levels in tumour containing compared with tumour free lymph nodes. In order to examine whether higher levels of DDR mRNA were present in the involved compared with the non-involved lymph node, the 10 3' RACE-PCR fragment radiolabelled with ^{32}P was used as a probe to hybridise with Northern blots of lymph node RNA. This probe recognised a single band of approximately 4kb on Northern blots. DDR mRNA was undetectable in the non-involved 15 lymph node and present in four of six metastasis-containing nodes (Figure 1). *In situ* hybridisation on a section of involved lymph node showed specific hybridisation over the metastasised tumour cells (Figure 2).

20 **Expression of DDR mRNA in breast tumours, breast carcinoma cell lines and mammary development**

The expression patterns of DDR in a panel of breast tumour RNAs and a number of breast carcinoma cell lines were examined by hybridising Northern blots with the ^{32}P labelled 3' RACE- 25 PCR fragment. DDR mRNA was present in normal breast tissue and in all the breast tumours tested (figure 3). Elevated levels of expression were detected in samples of 'normal' breast and carcinoma, both surgically removed from a pregnant woman. To examine DDR expression in mammary gland 30 development, a Northern blot of murine mammary gland poly (A)+ RNA was hybridised with the 3' RACE-PCR derived probe. Figure 4 shows that murine DDR mRNA (NEP, Zerlin *et al*, Oncogene, 8, 2731-2739 (1983)), see discussion) was detected in all stages of development. Expression was moderate in virgin glands, a 35 slight increase was seen in mid-pregnancy, during lactation very low levels of DDR mRNA were detected, and moderate levels reappeared during involution. During lactation casein mRNA comprises a large proportion of the total, this effectively dilutes the levels of other mRNAs; glyceraldehyde 3-phosphate

dehydrogenase (GAPDH) mRNA levels were decreased in these samples also. DDR mRNA expression was also detected in fat pad samples. The fat pad represents mammary tissue which has developed in the absence of epithelial cells due to the cauterisation of the nipple and surrounding tissue prior to epithelial outgrowth. Varying amounts of DDR mRNA were detected in the breast cancer cell lines examined, the highest were in MCF 7 and T47D and the lowest were in MDA MB:157 and BT 474. Expression was not detected in the fibrosarcoma cell line HT1080 (Figure 5).

Northern blot analysis revealed that DDR mRNA was present in normal breast and breast tumour tissue. *In situ* hybridisation was, therefore, performed on normal breast tissue and primary breast carcinoma samples to determine which cell types express DDR. In sections from three tumour samples, (Figures 6 a, b and c) hybridisation was predominantly over the tumour cells. DDR mRNA was undetectable in normal breast tissue adjacent to the tumour (Figure 6c top panel), and in all normal breast samples examined (data not shown). Figure 6c (top panel), shows a mass of invasive carcinoma surrounded by stromal cells in the top right of the field, with normal epithelial tissue in the bottom left of the field; hybridisation was specifically over the tumour cells, and DDR mRNA was undetectable in the normal epithelium and stromal cells. Figure 6c (middle panel) shows DDR positive cancer cells which have replaced the normal epithelial cells in the breast lobules. The malignant epithelial elements are surrounded by a dense lymphocytic infiltrate in which DDR was undetectable. A comparable result to Figure 6c was obtained using oligonucleotide probes, (date not shown). Figures 6a and c (lower panels) show results obtained with the random oligonucleotide probe and the sense riboprobe respectively, with no specific hybridisation. These controls were carried out for all *in situ* hybridisations (not shown in all cases).

Patterns of DDR expression in normal human tissues

A human poly (A)+ RNA multiple tissue Northern blot was screened with the 3' RACE-PCR probe (Figure 7a). DDR was

expressed at high levels in kidney and placental tissue, low levels were detected in the heart and lung, and expression was undetectable in the liver. A more extensive panel of human tissues was examined on total RNA Northern blots (Figure 7b).

5 DDR was expressed in a wide range of tissues, with relatively high levels in the kidney cortex and thyroid. By this analysis, the haematopoietic tissues bone marrow and spleen did not have detectable levels of DDR mRNA.

10 DISCUSSION

The initial differential screen identified DDR as a PTK expressed in involved but not in non-involved lymph nodes from breast cancer patients. Further studies revealed varying

15 levels of DDR mRNA in both normal breast and all of the breast carcinomas analysed. Elevated mRNA levels, relative to normal breast tissue, were found in both apparently normal breast tissue and breast carcinoma taken from the same pregnant patient. However, an examination of murine mammary gland

20 development revealed only a moderate increase in DDR mRNA in pregnancy. The higher levels of DDR in the human pregnant breast could be due to a focus of infiltrating carcinoma, as the specimen was taken from the tissue adjacent to a tumour. Alternatively, the murine mammary gland may differ from human

25 with respect to DDR expression during pregnancy. Unfortunately material was not available from the human pregnant breast for histopathological examination or *in situ* hybridisation studies to resolve this issue. *In situ* hybridisation studies were performed to determine which cells

30 in a particular tissue sample express DDR mRNA, and to give an indication of the relative abundance of mRNA expressed by different cell types. *In situ* hybridisation of a heavily infiltrated lymph node revealed DDR mRNA at high levels in the metastasising tumour cells and undetectable levels in the

35 adjacent cells. DDR mRNA was also shown to be present in tumour cells in primary breast carcinomas by *in situ* hybridisation. Where a direct comparison could be made, high levels of DDR mRNA were detected in the tumour cells but not in adjacent normal epithelial cells nor in tumour infiltrating

lymphocytes. By Northern analysis, DDR mRNA was present in normal human breast tissue, but by *in situ* hybridisation on human mammary tissue DDR has only been detected in tumour cells, which are epithelial in origin, and not in normal human breast epithelial or stromal cells. The question of the site of DDR expression in normal human mammary tissue is therefore unanswered; most likely cellular mRNA levels are too low for detection by *in situ* hybridisation. Nonetheless over expression of DDR occurs in some breast tumour cells when compared with normal mammary epithelium. Having demonstrated the presence of DDR mRNA in several sources of breast tumour tissue (in primary tumours, metastatic cells and carcinoma-derived cell lines) the expression in normal tissues was examined by Northern blotting. A wide range of levels were observed, ranging from high in the kidney cortex and thyroid, moderate in breast and lung, to undetectable amounts in the bone marrow, spleen, and liver. DDR expression is not restricted to any one tissue type, therefore, its role is not tissue specific. However, it is not ubiquitously expressed, thus a housekeeping function is unlikely and a cell specific role is probable.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT:

(A) NAME: The Institute of Cancer Research
 (B) STREET: 17A, Onslow Gardens
 (C) CITY: London
 (E) COUNTRY: Great Britain
 (F) POSTAL CODE (ZIP): SW7 3AL

(A) NAME: The Wellcome Foundation Limited
 (B) STREET: Unicorn House, 160 Euston Road
 (C) CITY: London
 (E) COUNTRY: Great Britain
 (F) POSTAL CODE (ZIP): NW1 2BP

(ii) TITLE OF INVENTION: Cell Growth Factor Receptors

(iii) NUMBER OF SEQUENCES: 13

(iv) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk
 (B) COMPUTER: IBM PC compatible
 (C) OPERATING SYSTEM: PC-DOS/MS-DOS
 (D) SOFTWARE: PatentIn Release #1.0, Version #1.25 (EPO)

(2) INFORMATION FOR SEQ ID NO: 1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 3754 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: double
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

(A) NAME/KEY: CDS
 (B) LOCATION: 142..2883

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 1:

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      Met Gly Pro Glu Ala Leu Ser Ser Leu Leu
      1                               5                               10
CTG CTG CTC TTG GTG GCA AGT GGA GAT GCT GAC ATG AAG GGA CAT TTT      219
Leu Leu Leu Leu Val Ala Ser Gly Asp Ala Asp Met Lys Gly His Phe
      15                               20                               25
GAT CCT GCC AAG TGC CGC TAT GCC CTG GGC ATG CAG GAC CGG ACC ATC      267
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      30                               35                               40
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Pro Asp Ser Asp Ile Ser Ala Ser Ser Ser Trp Ser Asp Ser Thr Ala
      45                               50                               55

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	Thr Phe Pro Pro Ala Pro Trp Trp Pro Pro Pro Pro Thr Asn	
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	Asn Arg Pro Gly Pro Arg Glu Pro Pro Pro Tyr Gln Glu Pro Arg Pro	
	475 480 485 490	
40	CGT GGG AAT CCG CCC CAC TCC GCT CCC TGT GTC CCC AAT GGC TCT GCG	1659
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	CCT GCC TGC CCG CAG GGC CTA TAT GAG CTG ATC CTT CGG TGC TGG AGC	2811
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	Arg Glu Ser Glu Gln Arg Pro Pro Phe Ser Gln Leu His Arg Phe Leu	
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	Ala Glu Asp Ala Leu Asn Thr Val	
	910	
	GGGAGCGATC CAGGGGAAGC CAGTGACACT AAAACAAGAG GACACAATGG CACCTCTGCC	2973
15	CCTTCCCCTC CCGACAGCCC ATCACCTCTA ATAGAGGCAG TGAGACTGCA GGCTGGGCCC	3033
	ACCCAGGGAG CTGATGCCCC TTCTCCCCTT CCTGGACACA CTCTCATGTC CCCTTCTGT	3093
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	ACCCACCTCT AGCCATCCCT TGGGGAAGGG TGGGGAGAAA TATAGGATAG ACACTGGACA	3213
	TGGCCCATTG GAGCACCTGG GCCCCACTGG ACAACACTGA TTCTGGACA GGTGGCTGGC	3273
25	CCCCAGCTT CTCTCTCCT GTCACACACT GGACCCCACT GGCTGAGAAT CTGGGGGTGA	3333
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30	CTCAGTCACC CCCCCTTCC CACCTGCACT CTTGTAGCTA GAACTTCTCT AAGCCTATAC	3513
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35	GGGTTGGACA TCTCTAGTGT AGTGCCACA TTGATTTTTC TATAACTACT TGGGTTTGTA	3633
	CATTTTTGGG GGGAGAGACA CAGATTTTTC CACTAATATA TGGACCTAGC TTGAGGCAAT	3693
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40	A	3754

(2) INFORMATION FOR SEQ ID NO: 2:

45	(i) SEQUENCE CHARACTERISTICS:
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	(B) TYPE: amino acid
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50	(ii) MOLECULE TYPE: protein
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	1 5 10 15
	Ser Gly Asp Ala Asp Met Lys Gly His Phe Asp Pro Ala Lys Cys Arg
	20 25 30
60	Tyr Ala Leu Gly Met Gln Asp Arg Thr Ile Pro Asp Ser Asp Ile Ser
	35 40 45
	Ala Ser Ser Ser Trp Ser Asp Ser Thr Ala Ala Arg His Ser Arg Leu
65	50 55 60
	Glu Ser Ser Asp Gly Asp Gly Ala Trp Cys Pro Ala Gly Ser Val Phe
	65 70 75 80

	Pro	Lys	Glu	Glu	Glu	Tyr	Leu	Gln	Val	Asp	Leu	Gln	Arg	Leu	His	Leu
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5	Val	Ala	Leu	Val	Gly	Thr	Gln	Gly	Arg	His	Ala	Gly	Gly	Leu	Gly	Lys
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			115					120					125			
10	Trp	Met	Gly	Trp	Lys	Asp	Arg	Trp	Gly	Gln	Glu	Val	Ile	Ser	Gly	Asn
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	Thr	Ala	Ile	Leu	Ile	Gly	Cys	Leu	Val	Ala	Ile	Ile	Leu	Leu	Leu	Leu
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65	Leu	Ile	Ile	Ala	Leu	Met	Leu	Trp	Arg	Leu	His	Trp	Arg	Arg	Leu	Leu
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60	Ala	Thr	Arg	Asn	Cys	Leu	Val	Gly	Glu	Asn	Phe	Thr	Ile	Lys	Ile	Ala
						770		775					780			
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65		785				790					795					800
	Gln	Gly	Arg	Ala	Val	Leu	Pro	Ile	Arg	Trp	Met	Ala	Trp	Glu	Cys	Ile
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33

Leu Met Gly Lys Phe Thr Thr Ala Ser Asp Val Trp Ala Phe Gly Val
 820 825 830
 5 Thr Leu Trp Glu Val Leu Met Leu Cys Arg Ala Gln Pro Phe Gly Gln
 835 840 845
 Leu Thr Asp Glu Gln Val Ile Glu Asn Ala Gly Glu Phe Phe Arg Asp
 850 855 860
 10 Gln Gly Arg Gln Val Tyr Leu Ser Arg Pro Pro Ala Cys Pro Gln Gly
 865 870 875 880
 Leu Tyr Glu Leu Met Leu Arg Cys Trp Ser Arg Glu Ser Glu Gln Arg
 885 890 895
 15 Pro Pro Phe Ser Gln Leu His Arg Phe Leu Ala Glu Asp Ala Leu Asn
 900 905 910
 20 Thr Val

(2) INFORMATION FOR SEQ ID NO: 3:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 7 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear
 (ii) MOLECULE TYPE: peptide
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 3:
 Arg Asp Leu Ala Ala Arg Asn
 1 5

(2) INFORMATION FOR SEQ ID NO: 4:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 32 base pairs
 (B) TYPE: nucleic acid
 (C) STRANDEDNESS: single
 (D) TOPOLOGY: linear
 (ii) MOLECULE TYPE: cDNA
 (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 4:
 GGAATTCTAG AMGSGACYTG GCVGCBAGRA AC

32

- (2) INFORMATION FOR SEQ ID NO: 5:
- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 7 amino acids
(B) TYPE: amino acid
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: peptide
- (ix) FEATURE:
(A) NAME/KEY: Modified-site
(B) LOCATION: 5..one-of(2)
(D) OTHER INFORMATION: /note= "Xaa at position 5 is Tyr or Phe"
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(A) NAME/KEY: Modified-site
(B) LOCATION: 7..one-of(2)
(D) OTHER INFORMATION: /note= "Xaa at position 7 is Val or Ile"
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 5:
- Asp Val Trp Ser Xaa Gly Xaa
1 5
- (2) INFORMATION FOR SEQ ID NO: 6:
- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 32 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: cDNA
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 6:
- GGAATTCTAG ACACSCCRWA RSWCCASACR TC
- (2) INFORMATION FOR SEQ ID NO: 7:
- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 35 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear
- (ii) MOLECULE TYPE: cDNA
- (xi) SEQUENCE DESCRIPTION: SEQ ID NO: 7:
- GACTCGAGTC GACATCGATT TTTTTTTTTT TTTT

(2) INFORMATION FOR SEQ ID NO: 8:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 21 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 8:

GTTGGGGAAA ATTCCACCAT C

(2) INFORMATION FOR SEQ ID NO: 9:

- (i) SEQUENCE CHARACTERISTICS:
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(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 9:

GGCATGAGCC GGAACCTC

(2) INFORMATION FOR SEQ ID NO: 10:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 10:

TCTCGATGAC CTGCTCGTCG GTGAGCTGCC

(2) INFORMATION FOR SEQ ID NO: 11:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 11:

CAGTCTCACT GCCTCTATTA GAGGTGATGG

(2) INFORMATION FOR SEQ ID NO: 12:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 12:

AAGCTGAGGA CAAGTACAGG AGCAGGCACA

(2) INFORMATION FOR SEQ ID NO: 13:

- (i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 30 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(xi) SEQUENCE DESCRIPTION: SEQ ID NO: 13:

TCAATGTGGC AGCTACACTA GAGATGTCCA

CLAIMS:

1. A method of screening a substance for potential utility as a therapeutic agent in the treatment of cancer which
5 comprises providing a standard system in which a protein tyrosine kinase or an active fragment thereof is able to develop a measurable effect, allowing the protein tyrosine kinase to develop that effect in the presence and absence of the said substance and measuring that effect, ability to
10 produce significant inhibition of the effect being taken as an indication of potential utility as a therapeutic agent, wherein the protein tyrosine kinase is characterised by the amino acid sequence shown in
SEQ ID NO. 1
15 or an amino acid sequence showing a significant degree of homology thereto.
2. A method as claimed in Claim 1 wherein the protein tyrosine kinase or an active fragment thereof is derived from
20 a recombinant expression system or a cellular source in which the protein is overexpressed.
3. A method as claimed in claim 2 wherein the recombinant expression system is an insect baculovirus, an immortalised
25 human breast cell line or a rodent fibroblast cell line.
4. A method as claimed in claim 2 or 3 wherein the measurable effect is protein tyrosine kinase activity which is measured by measuring autophosphorylation or
30 phosphorylation of a model substrate, by following incorporation of radioactive phosphate or by using anti-phosphotyrosine antibodies.
5. A method as claimed in Claim 1 wherein the measurable
35 effect is a phenotypic alteration conferred by expression of the protein tyrosine kinase or an active fragment thereof in a recombinant or non-recombinant cell line.

6. A method as claimed in Claim 1 wherein the measurable effect is the tumorigenic effect of a recombinant or non-recombinant cell line expressing the protein tyrosine kinase or an active fragment thereof when used as a xenograft in an animal.
7. A method as claimed in Claim 5 or 6 wherein the recombinant cell line is a primary immortalised human breast cell line or a rodent fibroblast cell line.
8. A therapeutic agent identified by a method as claimed in any of Claims 1 to 7.
9. A therapeutic agent as claimed in Claim 8 which is a chemical molecule of relatively low molecular weight.
10. A therapeutic agent as claimed in Claim 9 which is a staurosporine analogue, a tyrphostin or a flavenoid.
11. A therapeutic agent as claimed in Claim 8 which is a macromolecule.
12. A therapeutic agent as claimed in Claim 11 which is an antibody.
13. A therapeutic agent as claimed in claim 8 which is a peptide.
14. A therapeutic agent as claimed in claim 8 which is an antisense oligonucleotide capable of blocking translation of the mRNA encoding the protein tyrosine kinase.
15. A method for detecting a tyrosine kinase having an amino acid sequence as defined in
- SEQ ID NO. 1
- or a fragment thereof which comprises contacting a test sample with a specific antibody raised against an antigen from the

said amino acid sequence and determining whether there is any antigen antibody binding within the test sample.

16. A method for the detection in a sample of a nucleic acid sequence encoding a tyrosine kinase which comprises subjecting the sample or nucleic acid isolated therefrom to a method capable of detecting a nucleic acid sequence therein identical or substantially homologous to a defined nucleic acid sequence and identifying any sequence identical or substantially homologous to all or part of the DNA sequence defined in SEQ ID NO. 1, or mRNA which would be the transcription product of such DNA.
17. A method as claimed in Claim 16 wherein DNA is detected by Southern blotting and/or PCR using appropriate primers.
18. A method as claimed in Claim 16 wherein RNA is detected by Northern blotting, RNase protection studies and direct nucleic acid *in situ* hybridisation.
19. An enzyme-substrate complex which comprises a protein tyrosine kinase characterised by the amino acid sequence shown in SEQ ID NO. 1 or an amino acid sequence showing a significant degree of homology thereto and a therapeutic agent capable of modulating the activity of said protein tyrosine kinase.
20. A complex as claimed in Claim 19 wherein the therapeutic agent is a chemical molecule of relatively low molecular weight.
21. A complex as claimed in Claim 20 wherein the therapeutic agent is a staurosporine analogue, a tyrphostin or a flavenoid.
22. A complex as claimed in Claim 19 wherein the therapeutic

agent is a macromolecule.

23. A complex as claimed in Claim 22 wherein the therapeutic agent is an antibody.

24. A complex as claimed in Claim 19 wherein the therapeutic agent as a peptide.

25. A complex as claimed in Claim 19 wherein the therapeutic agent is an antisense oligonucleotide capable of blocking translation of the mRNA encoding the protein tyrosine kinase.

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FIG. 1

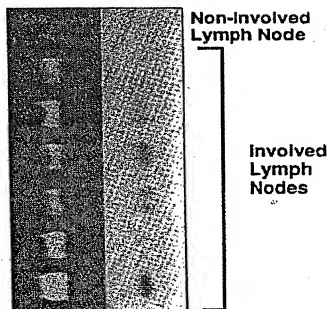


FIG. 2

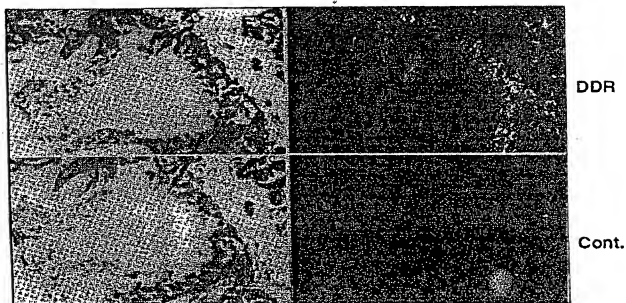


FIG. 4

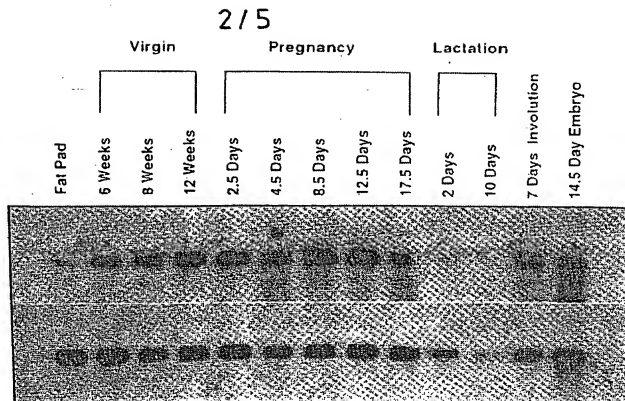
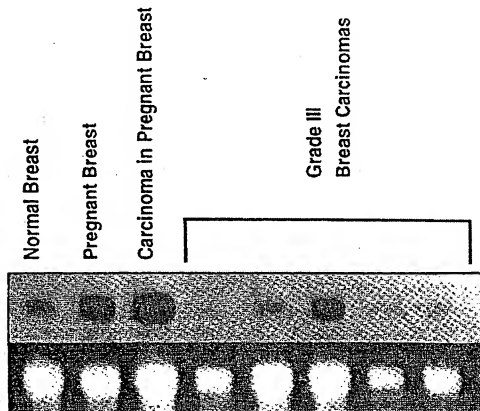


FIG. 3



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FIG. 5

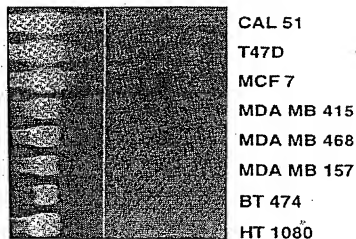
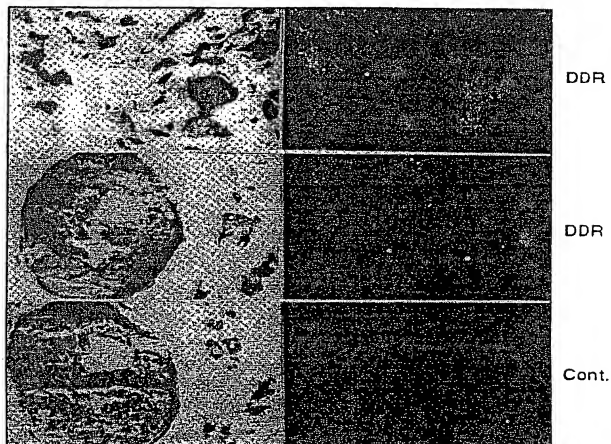


FIG. 6a



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FIG. 6b

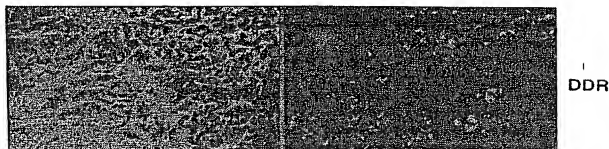
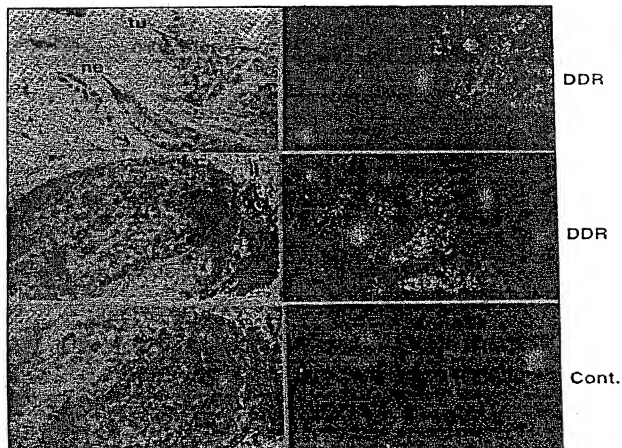
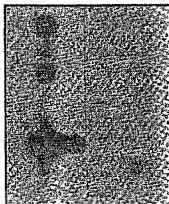


FIG. 6c



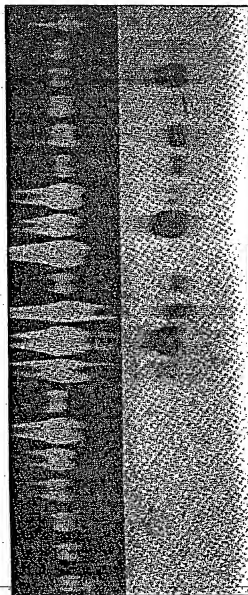
5/5

FIG. 7a



Heart
Brain
Placenta
Lung
Liver
Skeletal Muscle
Kidney
Pancreas

FIG. 7b



Oesophagus
Stomach
Gall Bladder
Ileum
Caecum
Colon
Tonsil
Thyroid
Spleen
Kidney Pelvis
Kidney Medulla
Kidney Cortex
Lung
Skin
Testis
Prostate
Myometrium
Endometrium
Breast
Bone Marrow

SUBSTITUTE SHEET (RULE 26)

INTERNATIONAL SEARCH REPORT

Intern. Application No. _____
PCT/GB 94/01480

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 6 G01N33/574 C12Q1/48 A61K31/55 A61K31/275 A61K31/35
 A61K39/395 A61K38/00 A61K31/70 G01N33/573 C12Q1/68
 C12N9/12 C12N15/11

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 G01N C12Q A61K C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF USA, vol.90, June 1993, WASHINGTON US pages 5677 - 5681 JEFFREY D. JOHNSON ET AL. 'A receptor tyrosine kinase found in breast carcinoma cells has an extracellular discoidin I-like domain' cited in the application see the whole document ---	1-25
Y	DRUGS OF THE FUTURE, vol.17, no.2, 1992 pages 119 - 131 TERRENCE R. BURKE, JR. 'Protein-tyrosine kinase inhibitors' cited in the application see the whole document ---	1-25



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

* Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
 "E" earlier document but published on or after the international filing date
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 "O" document referring to an oral disclosure, use, exhibition or other means
 "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
 "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
 "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
 "&" document member of the same patent family

Date of the actual completion of the international search

25 October 1994

Date of mailing of the international search report

08.12.94

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040, Tx. 31.651.epo.nl,
 Fax (+31-70) 340-3016

Authorized officer

Döpfer, K-P

INTERNATIONAL SEARCH REPORT

Intern. Application No.
PCT/GB 94/01480

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JOURNAL OF MEDICINAL CHEMISTRY, vol.34, 1991, WASHINGTON US pages 1896 - 1907 AVIV GAZIT ET AL. 'Tyrophostins. 2. Heterocyclic and alpha-substituted Benzylidenmalononitrile Tyrophostins as Potent Inhibitors of EGF Receptor and ErbB2/neu Tyrosine Kinases' cited in the application see the whole document ---	1-10, 19-21
Y	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF USA, vol.89, May 1992, WASHINGTON US pages 4285 - 4289 PAUL CARTER ET AL. 'Humanization of an anti-p185(HER2) antibody for human cancer therapy' cited in the application see the whole document ---	1-7, 11-13, 15, 19, 22-25
P,A	ONCOGENE, vol.8, no.12, December 1993, BASINGSTOKE GB pages 3433 - 3440 THOMAS KARN ET AL. 'Structure, expression and chromosomal mapping of TKT from man and mouse: a new subclass of receptor tyrosine kinases with a factor VIII-like domain' see the whole document ---	1-8, 11-19, 22-25
P,A	ONCOGENE, vol.9, no.1, January 1994, BASINGSTOKE GB pages 211 - 219 JOSE L. PEREZ ET AL. 'Identification and chromosomal mapping of a receptor tyrosine kinase with a putative phospholipid binding sequence in its ectodomain' see the whole document ---	1-8, 11-19, 22-25
P,A	ONCOGENE, vol.8, no.10, October 1993, BASINGSTOKE GB pages 2731 - 2739 MARIELBA ZERLIN ET AL. 'NEP: a novel receptor-like tyrosine kinase expressed in proliferating epithelia' cited in the application see the whole document ---	1-8, 11-19, 22-25
1 A	EP,A,0 504 914 (E.R. SQUIBB & SONS, INC.) 23 September 1992 see the whole document ---	1-8, 11-19, 22-25

-/--

INTERNATIONAL SEARCH REPORT

Intern. Appl. No.
PCT/GB 94/01480

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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